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RESEARCH ARTICLE

RELATIONSHIP OF THE IMPACTED MAXILLARY CANINE WITH THE MORPHOLOGY OF ADJACENT LATERAL INCISOR - A RETROSPECTIVE STUDY

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Abstract

Objective: This study aimed to inquireabout the location and inclination of the maxillary-impacted canine and its correlation with the morphology and root resorption of the adjacent lateral incisor by using CBCT.

Study design: The samples under investigation comprised 92 diagnosed cases of maxillary impacted canine, consisting of 35 males and 57 females, who met the study's inclusion criteria. Among these cases, 87 were unilateral, while 5 presented bilateral impactions, totaling 97 impacted canines. The morphological measurement of the lateral, angles between the central axis of the lateral incisor to the midline and the palatal plane,in both the impacted and non-impacted sides, were measured and compared.

Results: Statistically significant differences were obtained when comparing the morphological (crown length, root length, mesiodistal and buccolingual width of crown) and angular parameters (inclination to palatal plane, angulation to MSR) of the lateral incisor, root resorption of the lateral incisor with canine overlapping, canine cusp tip level with root resorption of the adjacent lateral incisor, canine angulation with root resorption of the adjacent lateral incisor.

Conclusion: The association between the morphologic and angular features of the maxillary lateral incisors and maxillary canine impaction was confirmed. Key predictors of maxillary canine impaction were identified as the crown and root length of the lateral incisor, the mesiodistal and buccolingual widths of the lateral incisor crown, and the angulation of both the lateral incisor and canine to the midline.

Introduction:-

Canine impaction is one of the most common dental abnormalities in orthodontic practice, posing a significant challenge for orthodontic treatment.With an incidence of between 1% and 3%, the maxillary canine is the second most frequently impacted tooth after the third molar. It is known that the impaction of maxillary canines occurs twice as much in females than in males. Unilateral canine impaction is more common than bilateral canine impaction in the ratio of 11.5:1. The incidence of palatally impacted canines is more common than buccally impacted canines with a ratio from 2:1 to 6:1.[1]

Multiple factors are responsible for canine impaction. The exact cause of canine impaction is unknown, but the most common causes for canine impaction are local and they are as follows- eruption disturbances during the stage of

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transition from mixed dentition, through to permanent dentition, tooth size discrepancies, prolonged retention or early shedding of primary canines, ankylosis, dilaceration of the root, etc.[2]

Early detection and intervention in cases of canine impaction can save time, money, and prevent the need for more complex treatments. Indicators of canine impaction include the presence of palatal and buccal bulges, delayed eruption of the permanent maxillary canine, prolonged retention of the deciduous canine, and displacement of adjacent teeth. Various radiographic methods, such as occlusal radiographs, periapical radiographs, and orthopantomograms (OPGs), can aid in detecting impacted canines. However, these 2D imaging techniques may result in superimposition of canine on adjacent teeth. Cone-beam computed tomography (CBCT) is preferred over 2D imaging for identifying the position of impacted canines due to its excellent tissue contrast, distortion-free slice images, and precise 3D images, which are particularly useful for measuring the crown and root length of anterior teeth.[3]

An impacted maxillary canine can lead to several complications, including the shifting of adjacent teeth, loss of arch length, resorption of neighboring teeth, cysts, and infections. A significant problem is the resorption of the lateral incisor root, which is typically asymptomatic and hard to diagnose.[4]Initially,lateral incisor resorption was estimated to be 12% based on 2-D radiography. However, this method had limitations due to image distortion and challenges in assessing the labial and palatal surfaces of the lateral incisor.With the advent of CBCT, the reported incidence increased to 38%. Further studies have found incidence rates ranging from 17% to 67%.[5]

Literature shows few studies on the severity of root resorption of the lateral incisor due to impacted canines and most of them have used 2-D radiography. There are very few CBCT studies concerning the various morphological factors of the lateral incisor, affecting the maxillary canine impaction and severity of root resorption of the lateral incisor.

Therefore, the primary objective of this research was to evaluate the position and characteristics of maxillary impacted canines and their correlation with the morphology and extent of root resorption of adjacent lateral incisors.We found a positive correlation between the morphologic and angular features of the maxillary lateral incisors and maxillary canine impaction by comparing the impacted side to the non-impacted side.

Material And Methods:-

This retrospective radiographic study was conducted in the Department of Orthodontics and Dentofacial Orthopaedics, Bareilly International University, Bareilly (U.P.). The CBCT scan of 92 diagnosed cases of maxillary impacted canines, consisting of 35 males and 57 females were included in the study as they fulfill the selection criteria among these cases, 87 were unilateral, while 5 presented bilateral impactions, totaling 97 impacted canines. No information regarding treatment or the purpose of the imaging was available. The only data collected included the age and sex of the patients.

All CBCT records were obtained in DICOM (Digital Imaging and Communication in Medicine) format from Carestream (version CS 9300, USA) Imaging system (120Kv, 5mA, voxel size of 0.2mm, a field of view of 10 x 10cm, and 14 sec. scan time) with TFT sensor technology. The contrast and brightness of the images were adjusted using the image processing tool in the software to ensure optimal visualization. The axial, coronal, and sagittal planes were created CBCT scans with good quality and resolution, absence of root resorption caused by periapical inflammation, dentigerous cyst, odontoma, craniofacial anomalies (cleft lip and palate), loss of one or more permanent teeth, several impacted teeth, etc.

In the Sagittal view, the crown and root length of the lateral incisor were assessed by measuring the linear distance using a reference line from the labial and palatal CEJ to the incisal tip representing the crown length and from CEJ to root apex representing the root length with the help of a linear measurement scale (figure 1 & 2). The inclination of the lateral incisor was assessed by measuring the angle formed between the long axis of the lateral incisor and the palatal plane (ANS to PNS) (figure 3).

In the Panoramic view, the vertical position of the maxillary impacted canine was categorized into the following categories: coronal to the CEJ level of the lateral incisor (Level 0), within the coronal third of the root (Level 1), within the middle third of the root (Level 2), and the apical third of the root (Level 3)[6](figure 4). The angle between the long axis of the lateral incisor to the mid-sagittal reference plane was classified as positive or negative concerning the mid-sagittal reference plane (MSR) (figure 5).The mesiodistal angular position of the impacted

canine was determined by measuring the angle between the long axis of the impacted canine and the mid-sagittal reference plane (figure 6).

The degree of overlap was visually assessed by comparing the location of the cusp tip of the impacted canine to the adjacent incisors on the panoramic view. The mesiodistal location of the impacted canine is classified based on its overlap with the adjacent teeth in a panoramic radiograph. Two vertical lines divide the lateral incisor and its surroundings into three sectors as follows: Sector I –It indicates the area where the tip of the impacted canine is positioned distal to the first line, Sector II – It indicates the area where the tip of the impacted canine lies mesial to sector I, Sector III – It indicates the whole area mesial to sector II, where the canine tip appears to have completely passed through the lateral incisor (figure 7).[7]

In the Axial view, the mesiodistal crown width was assessed by measuring from the broadest identifiable point on the mesial surface to the broadest identifiable point on the distal surface of the crown of the lateral incisor while the buccolingual crown width was determined by measuring from the widest identifiable point on the labial surface to the widest identifiable point on the palatal surface of the crown of the lateral incisor. Assessment of root resorption to maxillary lateral incisor was also visualized in axial view. The following damage scales were used: Grade A: No resorption of the lateral incisor root, Grade B: Resorption damaging up to half the width of the root wall of the lateral incisor, Grade C: Resorption of between half the thickness of the root wall until all the way but not through the wall of the lateral incisor root into the pulp canal, Grade D: Resorption exposing the pulp canal (figure 8).

Parameters like overlapping of impacted canine, angulation of canine, and inclination of lateral incisor were correlated with root resorption of the lateral incisor. In addition to this, parameters like root length of the lateral incisor, crown length of the lateral incisor, the inclination of the lateral incisor, angulation of lateral incisor to MSR, Crown width (buccolingual and mesiodistal) on the impacted side were compared with lateral incisor on the contralateral side.

Results:-

The interclass correlation coefficient values were less than 0.5 for linear and angular measurements. Thus, all the measurements were considered highly reliable.

The present study involved 92 subjects and 97 maxillary impacted canines were analysed on CBCT scans. In terms of gender, the prevalence of maxillary impacted canine was higher in females, (n=57, 62%) than in males (n= 35, 38%). Assessment of the side of canine impaction showed that approximately 46 canine impactions occurred on the right side and 51 Occurred on the left side. Buccally impacted canines (n=45) were predominant than the palatally (n=39) and bicortically (n=13) impacted canines in both genders. (Table 1)& (Graph1 & 2).

Our results revealed that the morphological and angular characteristics of the lateral incisors differed significantly between the impacted and non-impacted sides.The average shortening of the lateral incisor crown was 0.61mm on the impacted side. similarly, the lateral incisor roots were on average 0.46mm shorter on the impacted side compared to the opposite side.

In patients with canine impaction, crown narrowing was significant, both mesiodistal and buccolingual widths of the lateral incisor on the impaction side were 0.47mm and 0.28mm smaller respectively than on the contralateral sides. These results indicate that the shorter length and narrower crown width of the maxillary lateral incisor affect the impacted maxillary canine, as it can utilize a dominant local influence.

The angulation and inclination of the lateral incisors adjacent to the maxillary impacted canine were compared to the contralateral incisors. The angulation and inclination of the lateral incisor were lower on the impacted side compared to the non-impacted side. The differences were 3.05mm and 2.4mm respectively (Table 2).

Our study showed 82.2 percent of subjects with root resorption of the lateral incisor adjacent to the impacted canine. The Grade B root resorption was more common in the buccally impacted canine followed by palatal and bicortically impacted canine. While Grade C and Grade D, root resorption was more commonly observed in bi-cortically impacted canines. 14 percent of the total buccally impacted cases show no root resorption while 26.3 % of the total palatally impacted cases show no root resorption in grade A (Table 3).

A strong association was observed between the level of overlap (measured in sector) and the grade of root resorption of the lateral incisor. The percentages suggested that there was an increase in the incidence and severity of lateral incisor root resorption with an increase in the level of canine overlap across the adjacent lateral incisor. Severe root resorption (Grade D) associated with canines positioned in Sector III was 18.8% more than those positioned in Sector I and II, respectively. (Table 4)

In the vertical plane, more than half of the impacted canines were located in the coronal and middle third of the adjacent incisor root. Apically positioned crowns of involved canines predominantly showed 66.7%, Grade D root resorption, crown at the middle third and coronal third showed more Grade B (63.2%, 26.2%) root resorption respectively. (Table 5)

The current study revealed that the severity of root resorption in the lateral incisor was higher when the impacted canine had more mesial angulation. The increased prevalence of severely angulated maxillary canines in association with root resorption of lateral incisor was statistically significant. More precisely, higher values of these angulations cause severe root resorption. Regarding the maxillary lateral incisor inclination on the impacted side to the palatal plane (Inclination of lateral incisor) no statistical significance with the root resorption was shown. (Table 6)

Statistical Analysis:
Microsoft Excel (2019) was used to compile the data. The data collected was analyzed using IBM SPSS version 24. Alpha error was set at 0.05 and a 'p' value < o.o5 was considered significant. Descriptive statistics (Mean, stan. Deviation) was calculated for total samples. The chi-square test was used to compare the mean value of all parameters between overlapping of canine, gender, and root resorption of lateral incisor adjacent to the impacted canine. Graphically the values were represented.

Discussion:-

The missing or impacted canine is viewed as an evolutionary modification. The occurrence of maxillary canine impaction seems to fluctuate between 0.9% and 3%, contingent upon the specific population under scrutiny. Females are frequently noted as being more susceptible. In Asian populations, impacted canines typically occupy a buccal position, with a reported prevalence ratio of 5:1 compared to Europeans for palatal positioning.[8] In our investigation, we found a higher prevalence of buccally impacted canines compared to those impacted palatally.

This study outlines the relationships between maxillary canine impaction and the morphological features of the maxillary lateral incisor.There have been previous studies on this topic, but their results are of limited significance in that they analyzed the gross features of the maxillary lateral incisor based on 2D radiographs. However, in this study, we could examine the morphological and angular characteristics of the lateral incisor adjacent to the impacted canine using 3D reconstructed CT images.

92 DICOM images were evaluated in the present study, of which 87 were unilateral impacted canines and 5 bilateral impacted canines, totaling 97 impacted canines. For a reliable and reproducible comparison, we employed CBCT images of unilateral impaction cases, enabling us to use the subjects as their own controls and minimize inter-individual variability.Utilizing CBCT images offers numerous advantages, including highly detailed 3D imaging across multiple planes, eliminating superimpositions of structures, and reconstructing scanned anatomical features such as tooth roots, thereby facilitating optimal treatment planning for patients.

The number of females (62%) in the present study presenting with impacted canines was almost double that of males (38%) still there was no apparent association between gender and the incidence or severity of lateral incisor resorption. **A. Alassiry[9]** and **Simic S. et[10]** al also found in their study that the majority of the patients with impacted maxillary canines were female (62.5%) than males (34.3%).

This study reinforces earlier findings that the resorption of maxillary incisors following the abnormal eruption of maxillary canines is frequent. It emphasizes the necessity of considering this phenomenon in the treatment of patients experiencing significant deviations in the eruption of their maxillary canines. There was an observed correlation between the proximity of the impacted canine to the lateral incisor, and the subsequent resorption due to the impacted canine. The buccopalatal position of the impacted canine and root resorption of the adjacent lateral incisor showed a strong correlation. Furthermore, buccally impacted canines were predisposed to the maximum

prevalence of adjacent lateral incisor root resorption (86%), followed by palatally impacted canines (73.6%). These findings are in coordination with the study conducted by **Ericson et al.[11]**

The study's results indicated notable discrepancies in the angulation of maxillary lateral incisors adjacent to impacted and non-impacted canines relative to the midline. Specifically, the midline angulation of the lateral incisor was lower on the impacted side compared to the non-impacted side.Our findings may be attributed to the presence of maxillary impacted canines, which cause the axis of the adjacent lateral incisor to shift towards the midline, resulting in a narrower angle between this lateral incisor and the midline compared to the non-impacted side. This information is supported by **S. Koral et al.[12]& Bhikoo et al.[13]** who mentioned that the angle of the long axis of the lateral incisor crown to the midsagittal plane was smaller on the impacted side and had a negative mean difference value of 30.27.

The angle between the lateral incisor and the palatal plane on the affected side was reduced compared to the corresponding angle. **Montes-Diaz et al.[14]** also reported a significant reduction in inclination between the impaction group and control group, with 4.82º less inclination in the impaction group concerning the control group.

Kalavritinos et al.[15] Hang Wang et al.[16]& Chaushu et al.[6]observed a positive correlation between the appearance of resorption on the lateral incisor and the angle between the axis of the canine and adjacent lateral incisor. In our study also highly significant correlation was observed between root resorption of the lateral incisor and canine angulation.

The horizontal overlap of the impacted canine cusp over the adjacent lateral incisor to the root resorption was strongly associated. More precisely, in our study Grade D i.e. severe root resorption (18.8%) was observed in sector III. In this study, 80% of the impacted canines were found in sectors II and III (graph 2). Similar results were achieved by **Y. Kim et al.[17]**& **Jeff Lipshatz et al.[18]** who observed a significant association between the overlap (measured in sectors) and the grade of root resorption. These findings support the hypothesis that the mechanical force exerted by the impacted canine significantly contributes to root resorption **(Ericson et al.).[11]**

The root resorption of the adjacent lateral incisor and the canine cusp tip level were correlated in the current investigation. We also found that there were more resorption cases at the mid-root level followed by apical involvement and cervical root third involvement. According to the research done by **Jeff Lipshatz et al.[18]**most resorption cases were discovered at the mid-root level followed by apical and cervical root involvement.

The inclination of the lateral incisor did not seem to be associated with the severity of root resorption and could not be used to predict incidence.

The present study demonstrated significant differences in crown length, root length, crown width, angulation to the mid-sagittal plane (MSR), and inclination to the palatal plane between the impacted and non-impacted sides among patients with unilateral impacted canines. This suggests a strong association between maxillary canine impaction and reduced size of the adjacent lateral incisor crown and root. These findings align with similar results reported by Becker in 1981.

The etiological factors, including the morphological and angular characteristics of lateral incisors, can be identified even in the early stages. Hence, these findings may assist orthodontists in diagnosing, preventing, and planning treatments for maxillary-impacted canines.

This study utilized a retrospective design, which could be considered a limitation. Larger sample sizes would have been preferred. Further research is necessary to assess angular and linear measurements using CBCT images in a more extensive sample.

Conclusion:-

The present study found a significant relationship between the impacted maxillary canine with the morphology and root resorption of the adjacent lateral incisor. As a result, the following conclusions can be drawn:

1. The maxillary canine impaction occurred more frequently on the buccal side than the palatal side and more frequently in females than in males.

2. There are variations in the morphology and angular characteristics of the lateral incisors between the impacted and non-impacted sides.The crown width (mesiodistal & buccolingual), crown length, root length, angulation of lateral incisor to MSR, and inclination of lateral incisor to palatal plane were strong predictors based on CBCT radiographs and may assist the orthodontist in identifying the possibility of impaction.
3. The incidence of lateral incisor root resorption related to impacted maxillary canine in the present study was 82.6%.
4. There was a statistically significant correlation observed between the overlap of the impacted canine and root resorption of the lateral incisor.The extent of mesial displacement in canines is positively associated with both the frequency and severity of incisor resorption. Furthermore, the risk of resorption increases significantly with subsequent overlapping of sectors.
5. Lateral incisor root resorption was detected in both palatally and buccally impacted canines, but more severe root resorption was evident when the impacted canine was positioned buccally, especially when the canine crown overlapped the lateral incisor root to a greater extent.

Figure 1:- Crown length of lateral incisor.

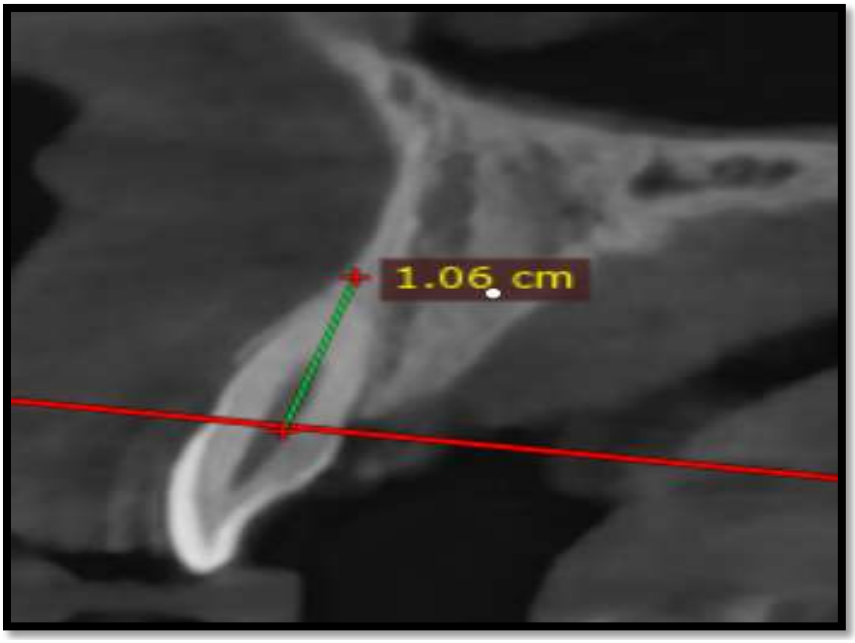


Figure 2:- Root length of lateral incisor.

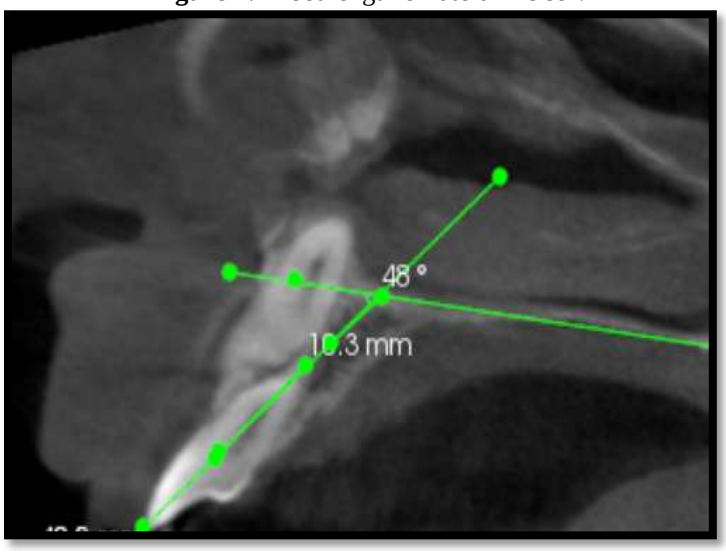


Figure 3:- Inclination of lateral incisor to the palatal plane.

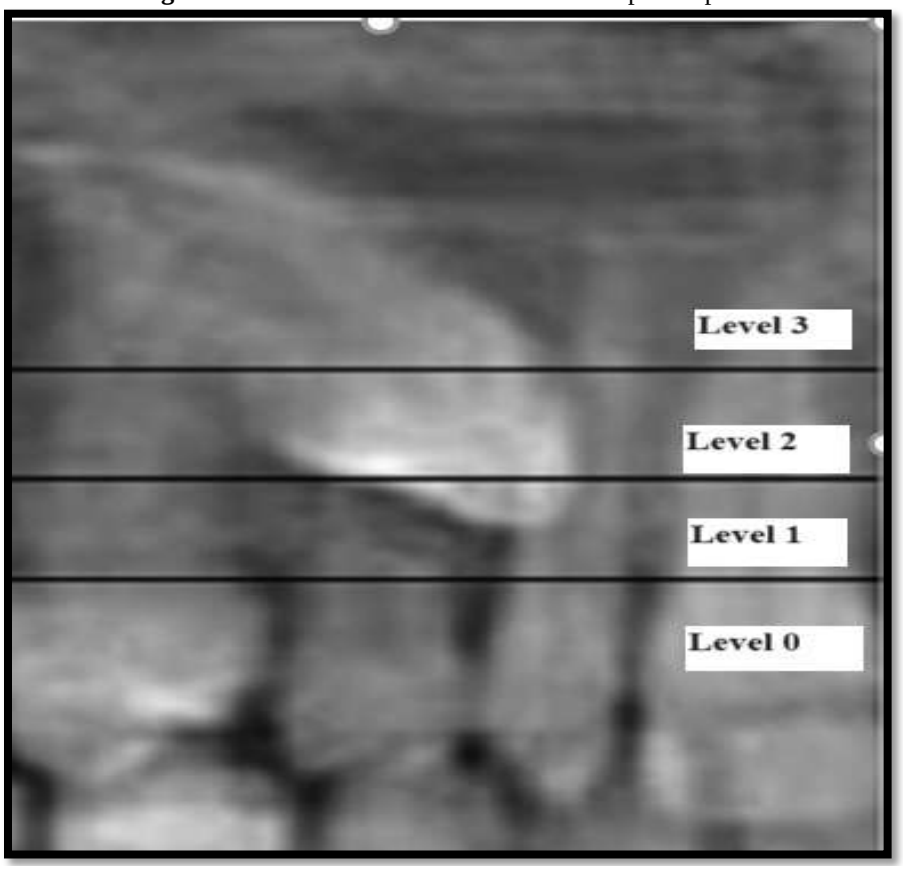


Figure 4:- Vertical level of canine cusp tip.

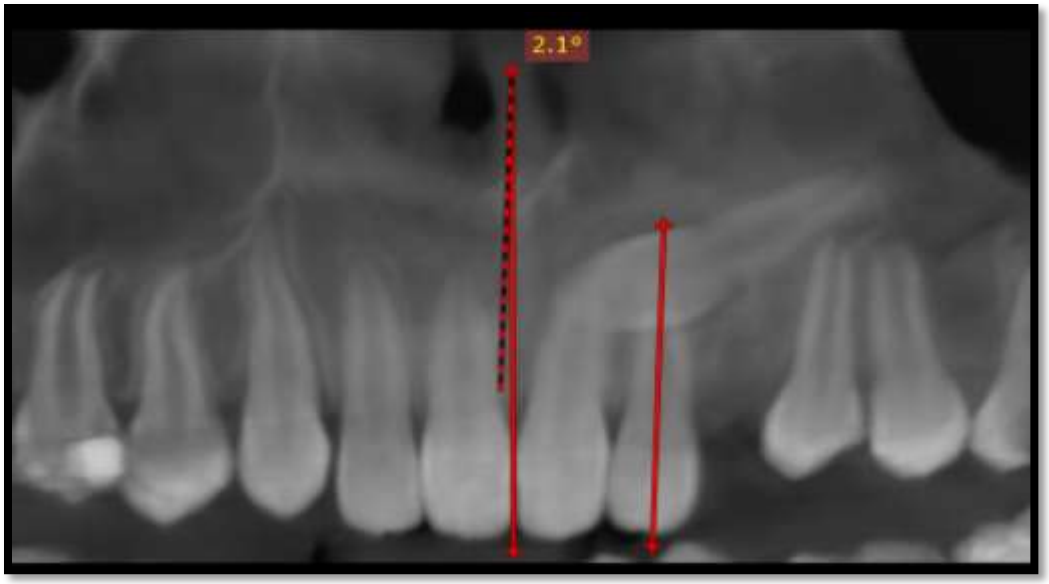


Figure 5:- Lateral incisor angulation with MSR.

Figure 6:- Canine angulation with MSR.

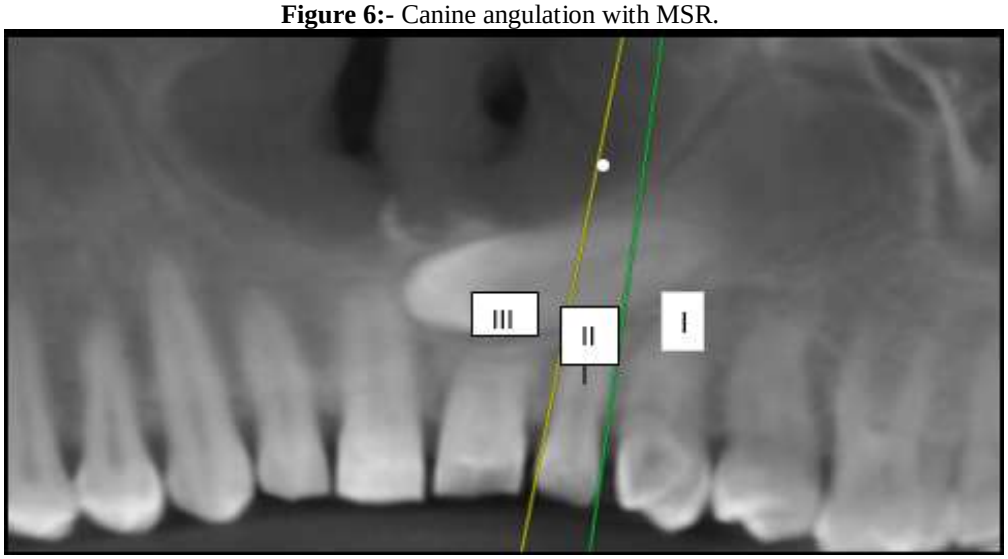
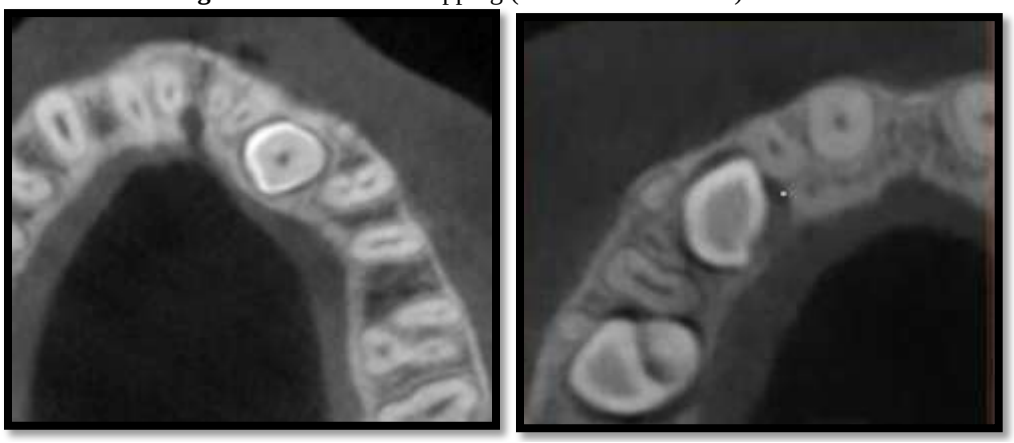
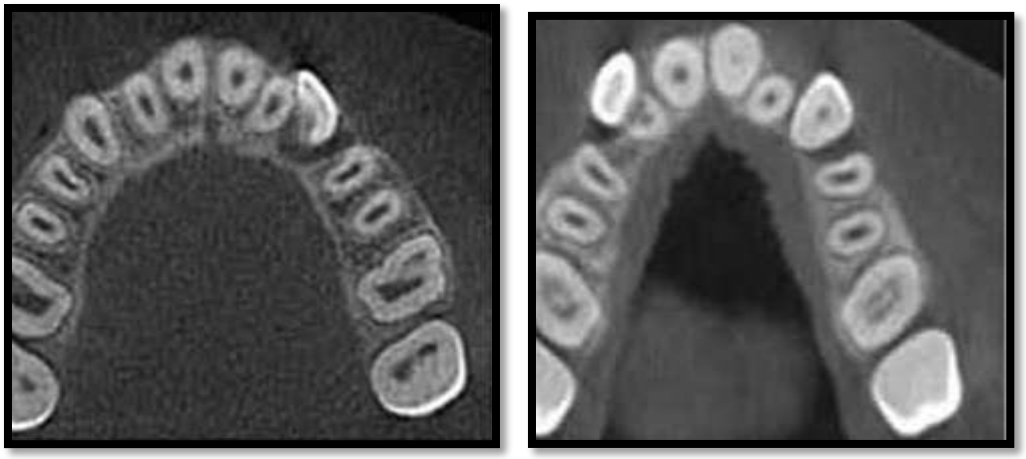


Figure 7:- Canine overlapping (Sector classification).



Grade A **Grade B**



Grade C **Grade D**

Figure 8:- Different grading of root resorption of the lateral incisor.

Table 1:- Frequency of Buccopalatal position of maxillary impacted canine.

Gender	Buccal	Palatal	Bicortical	Total
Male	14	13	8	35
Female	31	25	5	62

Table 2:- Comparison of morphologic and angular parameters of lateral incisor on impacted side to non-impacted side.

Parameters	Impacted	Contralateral	Difference	P value
RL of LI	10.98 ± 1.53	11.94 ± 1.13	-.9693478	.000**
CL of LI	8.81 ± 1.03	9.41 ± 1.04	-.5945652	.000**
Inclination of LI	68.76 ± 9.19	71.25 ± 8.51	-2.4945652	.049*
Angulation of LI to MSR	.29 ± 7.01	3.34 ± 4.06	-3.0543478	.000**
B-L	7.08 ± .73	7.36 ± .64	-.2800000	.007**
M-D	6.38 ± .62	6.86 ± .57	-.4785870	.000**
*** - significant ** - highly significant # - not significant**				

Table 3:- Root resorption of lateral incisor adjacent to the impacted canine in different Buccopalatal locations:

		Correlation of Root Resorption of LI vs BP position					
B/P position of canine		Grade A	Grade B	Grade C	Grade D	Total	Chi-square test
Buccal	COUNT	6	21	12	4	43	
	% within B/P position of canine	14.0%	48.8%	27.9%	9.3%	100.0%	$X^2 = 51.454^a$
Palatal	COUNT	10	16	11	1	38	df = 24
	% within B/P position of canine	26.3%	42.1%	28.9%	2.6%	100.0%	P value =0.000**
Bicortical	COUNT	0	4	4	3	11	

	% within B/P position of canine	0.0%	36.4%	36.4%	27.3%	100.0%
Total	COUNT	16	41	27	8	92
	% within the B/P position of canine	17.4%	44.6%	29.3%	8.7%	100.0%

Table 4:- Correlation of root of the lateral incisor with canine overlapping in different sectors.

			RR of LI Grade (mm)				Total	Chi – square test
			A	B	C	D		
Overlapping	Sector I	Count	12	7	2	0	21	$X^2 = 56.754^a$ df = 6 P value =.000**
		% within Overlapping of canine	57.1%	33.3%	9.5%	0.0%	100.0%	
	Sector II	Count	4	27	6	2	39	
		% within Overlapping of canine	10.3%	69.2%	15.4%	5.1%	100.0%	
	Sector III	Count	0	7	19	6	32	
		% within Overlapping of canine	0.0%	21.9%	59.4%	18.8%	100.0%	
Total		Count	16	41	27	8	92	
		% within Overlapping of canine	17.4%	44.6%	29.3%	8.7%	100.0%	

* - significant
** - highly significant
# - not significant

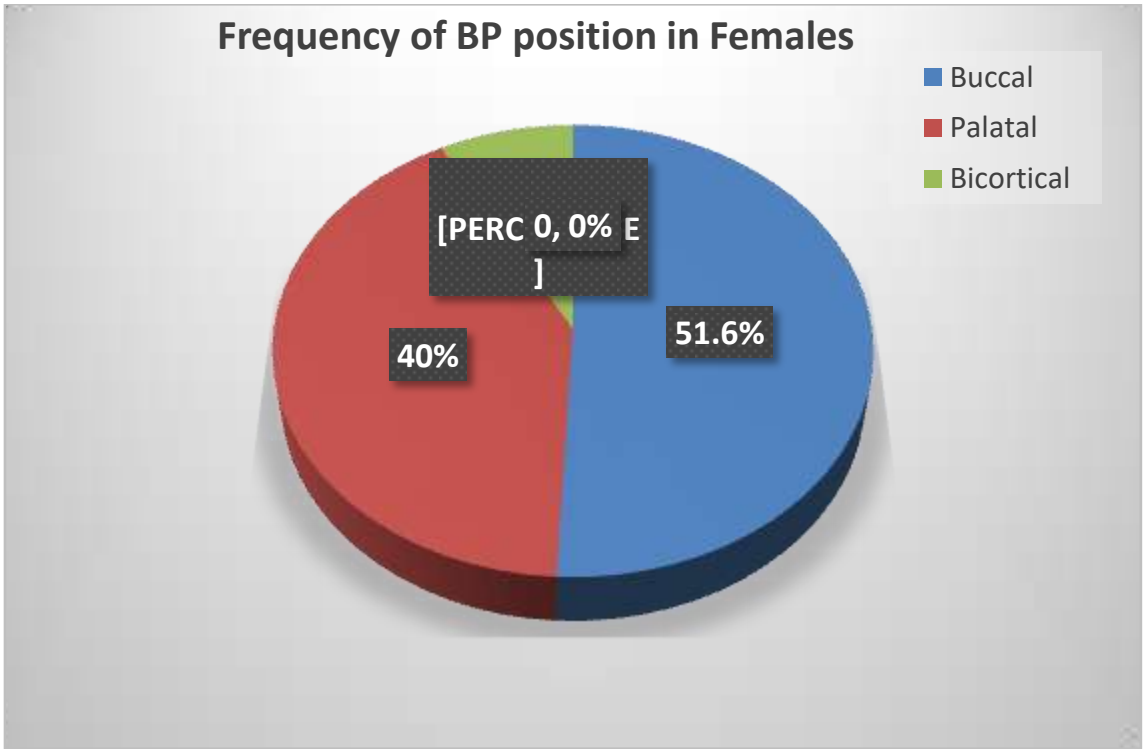
Table 5:- Correlation between canine cusp tip level (vertical level) with the root resorption of the adjacent lateral incisor.

			Canine tip level of LR root				**Total**	**Chi-square test**
			Level 0	Level 1	Level 2	Level 3		
Root Resorption of LI	Grade A	Count	1	8	7	1	17	$X^2 = 33.99^a$ df = 9 P value =0.000**
		% within Root Resorption of LI	5.9%	47.1%	41.2%	5.9%	100.0%	
	Grade B	Count	0	10	24	4	38	
		% within Root Resorption of LI	0.0%	26.3%	63.2%	10.5%	100.0%	
	Grade C	Count	1	2	10	15	28	
		% within Root Resorption of LI	3.6%	7.1%	35.7%	53.6%	100.0%	
	Grade D	Count	0	0	3	6	9	
		% within Root	0.0%	0.0%	33.3%	66.7%	100.0%	

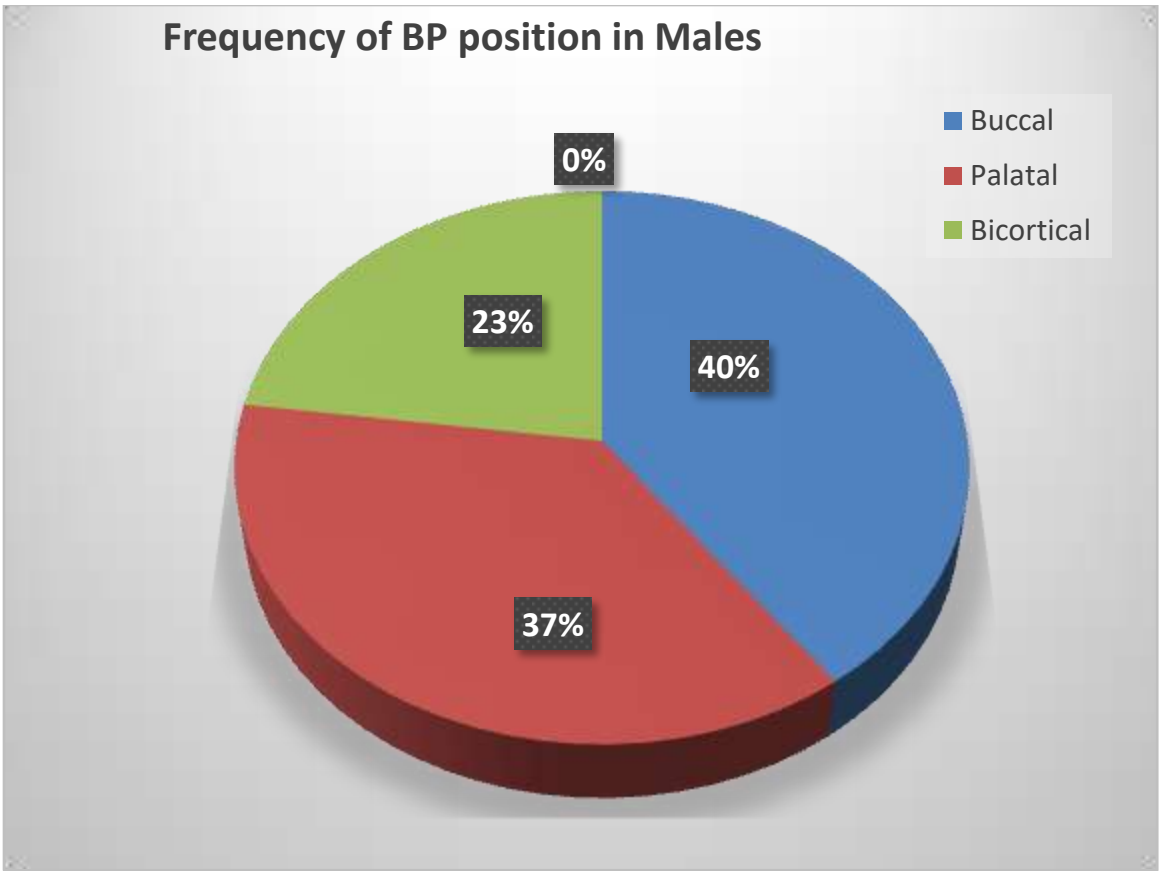
	Resorption of LI					
Total	Count	2	20	44	26	92
	% within Root Resorption of LI	2.2%	21.7%	47.8%	28.3%	100.0%

Table 6:- Correlation of the angulation of impacted canine to MSR with root resorption of lateral incisor.

Correlation of RR with Canine angulation		
Correlation between		RR of LI Grade (mm)
< of canine to MSR (degree)	Pearson Correlation	.652
	P value	.000**
	N	92
* - significant ** - highly significant # - not significant		



Graph 1:- Frequency of Buccopalatal position of maxillary impacted canine in Females.



Graph 2:- Frequency of Buccopalatal position of maxillary impacted canine in Males.

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